

TRANSMITTAL LETTER TO THE UNITED STATES

ATTORNEY'S DOCKET NUMBER 49568DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP 99/09059	12 November 1999	26 November 1998

TITLE OF INVENTION: REACTOR FOR CONTINUOUSLY CARRYING OUT GAS-LIQUID, LIQUID-LIQUID OR GAS-LIQUID-SOLID REACTIONS

APPLICANT(S) FOR DO/EO/US Stefan BERG, Peter ZEHNER, Regina BENFER, Joern MUELLER, Michael NILLES, Ralf SCHULZ, Dieter STUETZER

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. /X/ This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
 2. / / This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.
 3. /X/ This express request to begin national examination procedures (35 U.S.C.371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
 4. /x / A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
 5. /X/ A copy of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a./X/ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b./ / has been transmitted by the International Bureau.
 - c./ / is not required, as the application was filed in the United States Receiving Office (RO/USO).
 6. /X/ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
 7. /X/ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
 - a./X/ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b./ / have been transmitted by the International Bureau.
 - c./ / have not been made; however, the time limit for making such amendments has NOT expired.
 - d./ / have not been made and will not be made.
 8. /X/ A translation of the amendments to the claims under PCT Article 19(35 U.S.C. 371(c)(3)).
 9. /X / An oath or declaration of the inventor(s)(35 U.S.C. 171(c)(4)).
 10. / / A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).
- Items 11. to 16. below concern other document(s) or information included:
11. / / An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
 12. / X/ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
 13. /x / A FIRST preliminary amendment.
 - / / A SECOND or SUBSEQUENT preliminary amendment.
 14. / / A substitute specification.
 15. / / A change of power of attorney and/or address letter.
 16. /x / Other items or information.
 - International Search Report
 - International Preliminary Examination Report

U.S. Appln. No. (If Known) INTERNATIONAL APPLN. NO.
PCT/EP99/09059

ATTORNEY'S DOCKET NO.
49568

		CALCULATIONS	PTO USE ONLY
17. /X/ The following fees are submitted			
BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):			
Search Report has been prepared by the			
EPO or JPO.....	\$860.00	860.00	
International preliminary examination fee paid to USPTO			
(37 CFR 1.482).....	\$750.00		
No international preliminary examination fee paid to			
USPTO (37 CFR 1.482) but international search fee paid			
to USPTO (37 CFR 1.445(a)(2)).....\$700.00			
Neither international preliminary examination fee			
(37 CFR 1.482) nor international search fee			
(37 CFR 1.445(a)(2)) paid to USPTO\$ 970.00			
International preliminary examination fee paid to			
USPTO (37 CFR 1.482) and all claims satisfied pro			
visions of PCT Article 33(2)-(4).....\$96.00			
ENTER APPROPRIATE BASIC FEE AMOUNT = \$ 860.00			
Surcharge of \$130.00 for furnishing the oath or declaration			
later than // 20 // 30 months from the earliest			
claimed priority date (37 CFR 1.492(e)).			
Claims	Number Filed	Number Extra	Rate
Total Claims	9 -20		X\$18.
Indep. Claims	1 -3		X\$80.
Multiple dependent claim(s) (if applicable)		+270.	
TOTAL OF ABOVE CALCULATION		=	860.00
Reduction of 1/2 for filing by small entity, if applicable.			
Verified Small Entity statement must also be filed			
(Note 37 CFR 1.9, 1.27, 1.28).			
SUBTOTAL		=	860.00
Processing fee of \$130. for furnishing the English			
translation later than // 20 // 30 months from the			
earliest claimed priority date (37 CFR 1.492(f)). +			
TOTAL NATIONAL FEE		=	860.00
Fee for recording the enclosed assignment (37 CFR 1.21(h)).			
The assignment must be accompanied by an appropriate cover			
sheet (37 CFR 3.28, 3.31) \$40.00 per property = 40.00			
TOTAL FEES ENCLOSED		= \$	900.00
		Amount to be	
		refunded: \$	
		Charged \$	

a./X/ A check in the amount of \$ 900. to cover the above fees is enclosed.

b./ / Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c./X/ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0345. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

KEIL & WEINKAUF
1101 Connecticut Ave., N.W.
Washington, D. C. 20036

SIGNATURE

Herbert B. Keil

NAME

Registration No. 18,967

09/831402

JC08 Rec'd PCT/PTO 09 MAY 2001

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of)
BERG et al.) BOX PCT

International Application)
PCT/EP 99/00959)

Filed: November 12, 1999)

For: REACTOR FOR CONTINUOUSLY CARRYING OUT GAS-LIQUID,
LIQUID-LIQUID OR GAS-LIQUID SOLID REACTIONS

PRELIMINARY AMENDMENT

Honorable Commissioner of
Patents and Trademarks
Washington, D.C. 20231

Sir:

Prior to examination, kindly amend the above-identified application as follows:

IN THE CLAIMS

Please amend the claims as shown on the attached sheets.


REMARKS

The claims were amended in the international preliminary examination. The claims have been amended further to eliminate multiple dependency and to put them in better form for U.S. filing. No new matter is included. A clean copy of the claims is attached.

Favorable action is solicited.

Respectfully submitted,

KEIL & WEINKAUF


Herbert B. Keil
Reg. No. 18,967

1101 Connecticut Ave., N.W.
Washington, D.C. 20036

(202)659-0100

09/831402

AMENDED CLAIMS FOR OZ 49568

3. (amended) A reactor (1) as claimed in claim 1 [or 2], wherein the jet nozzle (2) is configured as a single-fluid nozzle and, optionally, a facility for introducing one or more gaseous reactants, preferably one or more, in particular from one to three, annular pipes having a plurality of orifices, in particular in the lower region of the reactor or distributed over the height of the reactor, is (are) additionally provided in the annular space between guide tube (4) and interior wall of the reactor.
4. (amended) A reactor (1) as claimed in claim 1[or 2], wherein the jet nozzle (2) is configured as a three-fluid or two-fluid nozzle.
5. (amended) A reactor (1) as claimed in [any of claims 1 to 4] claim 1, which has an aspect ratio $1/d$ of from 3 to 10, preferably from 6 to 10.
6. (amended) A reactor (1) as claimed in [any of claims 1 to 5] claim 1, wherein the ratio of the diameters of guide tube (4) and reactor (1) is in the range from 0.25 to 0.5, particularly preferably in the range from 0.28 to 0.33.
7. (amended) A reactor (1) as claimed in [any of claims 1 to 6] claim 1, wherein an impingement plate (6) is located in the region of the reactor below the lower end of the guide tube (4), preferably at a distance of one guide tube diameter.
8. (amended) A continuous process for carrying out gas-liquid or gas-liquid-solid reactions in a reactor (1) as claimed in [any of claims 1 to 7] claim 1, wherein the major part of the reaction mixture, corresponding to from 2 to 30 times, preferably from 5 to 10 times, the volume flow of the reaction mixture pumped around the external circuit flows in an internal loop through the guide tube (4)

from the top downward and through the annular space between guide tube (4) and interior wall of the reactor from the bottom upward.

9. (amended) [The use of an apparatus as claimed in any of claims 1 to 7 or a process as claimed in claim 8 for, in particular,] A process as defined in claim 8, wherein the reaction is a strongly exothermic gas-liquid or gas- liquid-solid [reactions, preferably] for hydrogenation[s], oxidation[s], ethoxylation[s], propoxylation[s], hydroformylation[s] or aldol condensation[s] reaction.

CLEAN CLAIMS OZ49568

1. A reactor (1) of high cylindrical construction for continuously carrying out gas-liquid-solid reactions, provided with a downward-directed jet nozzle (2) via which the starting materials and the reaction mixture are fed in and which is located in the upper region of the reactor, and provided with an offtake (3), preferably in the lower region of the reactor, via which the reaction mixture is conveyed via an external circuit back to the jet nozzle (2) by means of a pump (P), where a guide tube (4) which extends essentially over the total length of the reactor (1) with the exception of the reactor ends and has a cross-sectional area in the range from one tenth to one half of the cross-sectional area of the reactor (1) is located concentrically in the reactor (1), and the jet nozzle (2) is located above the upper end of the guide tube (4), preferably at a distance of from one eighth of the guide tube diameter to one guide tube diameter, or projects into the guide tube (4) to a depth up to a plurality of guide tube diameters, and a heat exchanger provided with heat exchange tubes is integrated into the annular space, wherein the heat exchanger tubes run parallel to the guide tube (4).
2. A reactor (1) as claimed in claim 1, wherein the heat exchanger tubes of the heat exchanger are welded in between plates.
3. A reactor (1) as claimed in claim 1, wherein the jet nozzle (2) is configured as a single-fluid nozzle and, optionally, a facility for introducing one or more gaseous reactants, preferably one or more, in particular from one to three, annular pipes having a plurality of orifices, in particular in the lower region of the reactor or distributed over the height of the reactor, is (are) additionally provided in the

annular space between guide tube (4) and interior wall of the reactor.

4. A reactor (1) as claimed in claim 1, wherein the jet nozzle (2) is configured as a three-fluid or two-fluid nozzle.
5. A reactor (1) as claimed in claim 1, which has an aspect ratio $1/d$ of from 3 to 10, preferably from 6 to 10.
6. A reactor (1) as claimed in claim 1, wherein the ratio of the diameters of guide tube (4) and reactor (1) is in the range from 0.25 to 0.5, particularly preferably in the range from 0.28 to 0.33.
7. A reactor (1) as claimed in claim 1, wherein an impingement plate (6) is located in the region of the reactor below the lower end of the guide tube (4), preferably at a distance of one guide tube diameter.
8. A continuous process for carrying out gas-liquid or gas-liquid-solid reactions in a reactor (1) as claimed in claim 1, wherein the major part of the reaction mixture, corresponding to from 2 to 30 times, preferably from 5 to 10 times, the volume flow of the reaction mixture pumped around the external circuit flows in an internal loop through the guide tube (4) from the top downward and through the annular space between guide tube (4) and interior wall of the reactor from the bottom upward.
9. A process as defined in claim 8, wherein the reaction is a strongly exothermic gas-liquid or gas-liquid-solid for hydrogenation, oxidation, ethoxylation, propoxylation, hydroformylation or aldol condensation reaction.

AS ORIGINALLY FILED

**Reactor for continuously carrying out gas-liquid, liquid-liquid or
gas-liquid-solid reactions**

- 5 The present invention relates to a reactor for continuously carrying out gas-liquid, liquid-liquid or gas-liquid-solid reactions, to a process and to a use of the reactor.

Gas-liquid mass transfer and the removal of heat are the rate-determining steps in many chemical processes. To improve mass transfer at the phase interface, the use of ejectors, i.e. devices which utilize the kinetic energy of a high-velocity liquid jet to draw in and disperse the gas phase, has been proposed for such reactions. The high energy input creates high turbulence and generates high shear forces in the ejector, so that the gas is dispersed in the form of very small bubbles, i.e. a very high gas-liquid interfacial area per unit volume is generated. In the literature, values of from 40 000 to 70 000 m²/m³ for the phase boundary area per unit volume are described for ejectors, compared to from 500 to 2 500 in the overall system, i.e. outside the ejector (cf. Chem. Eng. Sci. Vol. 47, No. 13/14 pp. 3557 ff, 1992).

- 20 Apparatuses for carrying out gas-liquid or gas-liquid-solid reactions using ejectors are known as loop venturi reactors and are described, for example, in DE-A-4323687 in conjunction with a continuous process for preparing aromatic diamines and polyamines by catalytic hydrogenation of the corresponding polynitro compounds. The ejector, i.e. a two-fluid jet nozzle with fixed impulse exchange tube and diffuser in which circulated liquid mixture and gaseous reactant
- 25

(hydrogen) are brought into contact, is located at the end of the loop venturi reactor. A proportion of the length of the ejector projects through the gas-liquid phase interface into the liquid. The gas dispersion power is high in the ejector itself, but not in the remaining reactor volume which, in terms of flow and residence time behavior, has pure bubble column characteristics. In this reactor volume outside the ejector, small and large random eddies with comparatively low mass transfer keep the catalyst in the suspended state. The gas content in the reactor is established predominantly on the basis of the properties of the materials but to a lesser extent also on the basis of the initial dispersion. The heat of reaction which is liberated is removed via an external heat exchanger in the pump circuit.

EP-A-263 935 describes stirred tank reactors for carrying out strongly exothermic reactions, in which the heat liberated is removed via Field tube heat exchangers at the place where it arises. As is known, the term Field tube heat exchanger refers to heat exchangers which have a bundle of parallel double-walled tubes, where the ends of the outer tubes projecting into the reactor space are closed and the corresponding ends of the inner tubes are open, so that the heat exchange medium flows via a feed space located outside the reactor space into the inner tubes and flows out via the space between inner and outer tubes and an outlet space. Such heat exchangers have a high ratio of heat exchange area to volume of the reaction space and are thus particularly effective for removing the heat of reaction liberated. However, the process described has the disadvantage that mixing of the phases is not ensured, with the consequence that there is increased occurrence of uncontrollable secondary reactions resulting in a reduction in yield and that the cooling surfaces become covered with resinous compounds and/or catalyst.

It is an object of the present invention to provide a reactor for gas-liquid, liquid-liquid or gas-liquid-solid reactions which ensures intensive mixing of the phases in the entire reaction volume and thus ensures improved efficiency and an improved space-time yield.

In one embodiment, it is also an object of the invention to ensure that the reactor is largely isothermal, i.e. there is a very small temperature gradient over the height of the reactor.

A further object of the invention is to provide a continuous process for gas-liquid, liquid-liquid or gas-solid reactions using a reactor according to the present invention.

- 5 The present invention starts out from a reactor for gas-liquid or gas-liquid-solid reactions having a high cylindrical construction provided with a downward-directed jet nozzle via which the starting materials and the reaction mixture are fed in and which is located in the upper region of the reactor, and provided with an
10 offtake, preferably in the lower region of the reactor, via which the reaction mixture is conveyed via an external circuit back to the jet nozzle by means of a pump.

- 15 In the reactor of the present invention, a guide tube which extends essentially over the total length of the reactor with the exception of the reactor ends and has a cross-sectional area in the range from one tenth to one half of the cross-sectional area of the reactor is located concentrically in the reactor, and the jet nozzle is located above the upper end of the guide tube, preferably at a distance of from one eighth of the guide tube diameter to one guide tube diameter, or projects into the guide tube to a depth up to a plurality of guide tube diameters, and a heat exchanger, in
20 particular a heat exchanger having heat exchange tubes, preferably running parallel to the guide tube, welded in between plates, is integrated into the annular space.

- It has been found that the mass transfer and heat transport limitations are largely or completely eliminated and the overall reaction thus proceeds under purely kinetic
25 control in such a reactor.

- The solution provided by the present invention, according to which the major part of the reaction mixture is conveyed in a directed internal loop and only a small part of the reaction mixture which is necessary for driving the loop flow is pumped
30 around an external circuit, is energetically advantageous.

- As a result of the flow conditions being unambiguously defined in the entire reactor volume, i.e. the most important parameters for design of the reactor, viz. flow velocities, gas contents, backmixing, mixing time and residence time
35 behavior, can be determined sufficiently precisely, the reactor of the present invention is capable of direct scale-up.

The term jet nozzle refers, as is known, to a tube which tapers in the flow direction; the jet nozzle can be configured as a three-fluid or two-fluid nozzle, optionally with impulse exchange tube and diffuser, or as a single-fluid nozzle.

- 5 When using a single-fluid nozzle, one or more gaseous reactants can additionally be introduced into the gas space at the top of the reactor or via suitable facilities, preferably via one or more, in particular from one to three, annular pipes having a plurality of orifices, particularly in the lower region of the reactor or distributed over the height of the reactor, into the annular space between guide tube and
10 interior wall of the reactor. However, the gas can also be fed in below the impingement plate or directly into the gas space above the single-fluid nozzle. The buoyancy generated by the gas bubbles helps to drive the internal loop flow.

- 15 The offtake for the reaction mixture can in principle be located at any height on the reactor, preferably in the lower region of the reactor, particularly preferably at the bottom of the reactor. Part of the reaction mixture is taken off via the offtake by means of a pump and, optionally after solid components, in particular suspended catalyst, have been separated off, for example in a crossflow filter, fed back to the jet nozzle in the upper part of the reactor.

- 20 For the purposes of the present invention, the term guide tube refers to an internal tube which is located concentrically in the vertical cylindrical reactor and extends over virtually the entire length of the reactor with the exception of the reactor ends. The upper end of the guide tube always has to be covered with liquid, i.e. it must
25 be located below the upper gas separation space which, according to the present invention, makes up from about 3 to 15% of the total volume of the reactor, in particular from 5 to 7% of the total volume of the reactor. The upper end of the guide tube has to be at a distance from the downward directed jet nozzle whose axis is preferably coincident with that of the guide tube. The relative positioning of
30 nozzle and guide tube and the internal fill level can be used to set the gas content in the reaction mixture.

- The jet nozzle preferably has its opening in the region of the interface between continuous gaseous and liquid phases, i.e. the surface of the liquid. In this case, the
35 gas content in the reaction volume can be altered within certain limits by raising or lowering the level of liquid. If, for example, the nozzle is dipped in the liquid by raising the level of liquid, the gas content of the reaction mixture becomes smaller,

while lowering the level of liquid below the outlet of the jet nozzle results in larger amounts of gas being drawn into the reaction volume.

5 The guide tube preferably has a cross-sectional area in the range from one tenth to one half of the cross-sectional area of the reactor. The lower end of the guide tube is in the lower region of the reactor, preferably in the region of the cylindrical end of the reactor.

10 A heat exchanger, in particular a heat exchanger having heat exchange tubes, preferably running parallel to the guide tube, welded in between plates, is integrated into the annular space between guide tube and interior wall of the reactor. This ensures, particularly in the case of strongly exothermic reactions, that the reactor is largely isothermal, i.e. has a very small temperature gradient over the height of the reactor, since the heat of reaction is removed where it arises. In
15 addition, the reliability of the process is improved compared to a process employing cooling in the external circuit, since the reactor cooling still functions if the pump for the external circuit fails. If the cooling water supply fails, cooling still functions until all the cooling water in the heat exchange tubes has been vaporized.

20 However, it is also possible to integrate heat exchangers having a different construction, in particular Field tube heat exchangers, into the annular space.

The reactor preferably has an aspect ratio, i.e. the ratio of length (l) to diameter (d), of from 3 to 10, more preferably from 6 to 10. The reactor can be constructed with
25 this high aspect ratio because of the directed internal loop flow. As a result of the high aspect ratio, the gas content in the reaction volume can be altered by means of only small changes in the amount of liquid in the reactor, because this alters the relative positioning of jet nozzle and liquid surface.

30 The ratio of the diameters of the guide tube and the reactor is preferably in the range from 0.25 to 0.5, preferably in the range from 0.28 to 0.33.

The lower region of the reactor is preferably provided with an impingement plate installed below the lower end of the guide tube, essentially perpendicular to the
35 guide tube and preferably at a distance of from one to two guide tube diameters from the guide tube. The impingement plate is preferably configured as a disk having a diameter greater than the diameter of the guide tube and smaller than the

internal diameter of the reactor and a thickness determined by the mechanical strength of the preferably metallic material of construction, i.e. in the range of about 5-10 mm. The impingement plate not only has the function of reversing the flow but also has the task of preventing gas bubbles from being carried into the external circuit and damaging the pump.

The present invention also provides a continuous process for carrying out gas-liquid or gas-liquid-solid reactions in a reactor as described above, wherein the major part of the reaction mixture, corresponding to from 2 to 30 times, preferably from 5 to 10 times, the volume flow of the reaction mixture pumped in the external circuit, flows in an internal loop through the guide tube from the top downward and through the annular space between guide tube and interior reactor wall from the bottom upward. For the purposes of the present invention, the expression internal loop (flow) refers to a circulation of the reaction mixture within the reactor which is driven by the liquid jet produced by the downward-directed jet nozzle located in the upper region of the reactor. This downward-directed liquid jet produces a downward flow in the guide tube which, after leaving the guide tube, is deflected in the lower region of the reactor and is directed upward in the annular space between guide tube and interior wall of the reactor. At the upper end of the guide tube, the liquid is once again drawn in by the driving jet, mixed with this and turned downward again. The loop flow can be assisted by addition of one or more gaseous reactants into the annular space between guide tube and interior wall of the reactor by exploiting the buoyancy of the gas.

The liquid jet disperses the circulating gas present in the form of gas bubbles in the two-phase flow at the upper end of the guide tube, in the vicinity of the jet nozzle, as a result of which very high gas transfer coefficients and phase boundary areas per unit volume are achieved. Furthermore, the liquid jet draws in the gas from the gas separation space in the upper part of the reactor and disperses it.

The apparatus and process of the present invention are particularly useful for highly exothermic gas-liquid, liquid-liquid or gas-liquid-solid reactions, preferably suspension-catalyzed hydrogenations, organic oxidations, ethoxylations, propoxylations or aldol condensations.

The application of the process and apparatus of the present invention to the abovementioned reactions makes it possible to achieve better space-time yields,

milder reaction conditions, in particular in respect of the pressure and possibly the temperature, reduced reaction volumes, lower production costs due to energy savings, possibly reduced capital costs and improved safety.

- 5 The invention is illustrated below by means of a figure and an example.

The single figure shows a longitudinal section through a reactor 1 according to the present invention having a jet nozzle 2 via which the starting materials and the reaction mixture can be fed in and which is locked in the upper region of the reactor and having an offtake 3 in the lower region of the reactor, via which the reaction mixture is conveyed in an external circuit by means of a pump P and fed back to the jet nozzle 2. A concentric guide tube 4 extending over the major part of the reactor length with the exception of the reactor ends is located in the reactor 1. The figure shows an impingement plate 7, which is preferably present, below the lower end of the guide tube 4. A heat exchanger which is depicted in the figure as a Field tube heat exchanger with feed space 5 and discharge space 5' for the coolant K and with heat exchange tubes 6 is also preferably provided. In a further preferred embodiment, the heat exchanger can be in the form of heat exchange tubes, preferably running parallel to the guide tube 4, welded in between plates.

Example

In a reactor as shown in Figure 1 having a reaction volume of about 0.05 m^3 and provided with 36 parallel Field tubes which have a total cooling area of about 2.5 m^2 and into which a cooling water stream of about $1 \text{ m}^3/\text{h}$ and having a temperature of about 35°C is fed, 30.3 kg/h of propionaldehyde are introduced at 75°C into a fast-flowing mixture consisting of about 84% of propionic acid, about 15% of propionaldehyde and not more than 1% of by-products, in particular organic acids and alcohols, by means of a metering pump. A pressure of 23 bar is set in the reactor by simultaneous introduction of $31 \text{ standard m}^3/\text{h}$. To maintain the loop flow, a volume of $2.5 \text{ m}^3/\text{h}$ is circulated around the external product circuit. The pressure in the jet nozzle is about 3 bar above the reactor pressure and the specific power input is about 5 kW/m^3 .

- 35 The reaction proceeds under virtually isothermal conditions, since the heat of reaction is removed where it arises. The maximum reaction temperature in the lower third of the reactor is 76°C .

A substream of 38.8 kg/h of the reaction mixture consisting of 84% of propionic acid, about 15% of propionaldehyde and less than 1% of by-products, in particular organic acids and alcohols, is taken off continuously. This corresponds to a space-time yield of 650 kg/m³h. The unreacted propionaldehyde can be separated off by thermal means, in particular by distillation, or reacted further in a cascade of two reactors according to the present invention connected in series with additional use of a reaction tube. When using a cascade of two reactors according to the present invention, the total propionaldehyde conversion is 98.7% at a selectivity of about 96%.

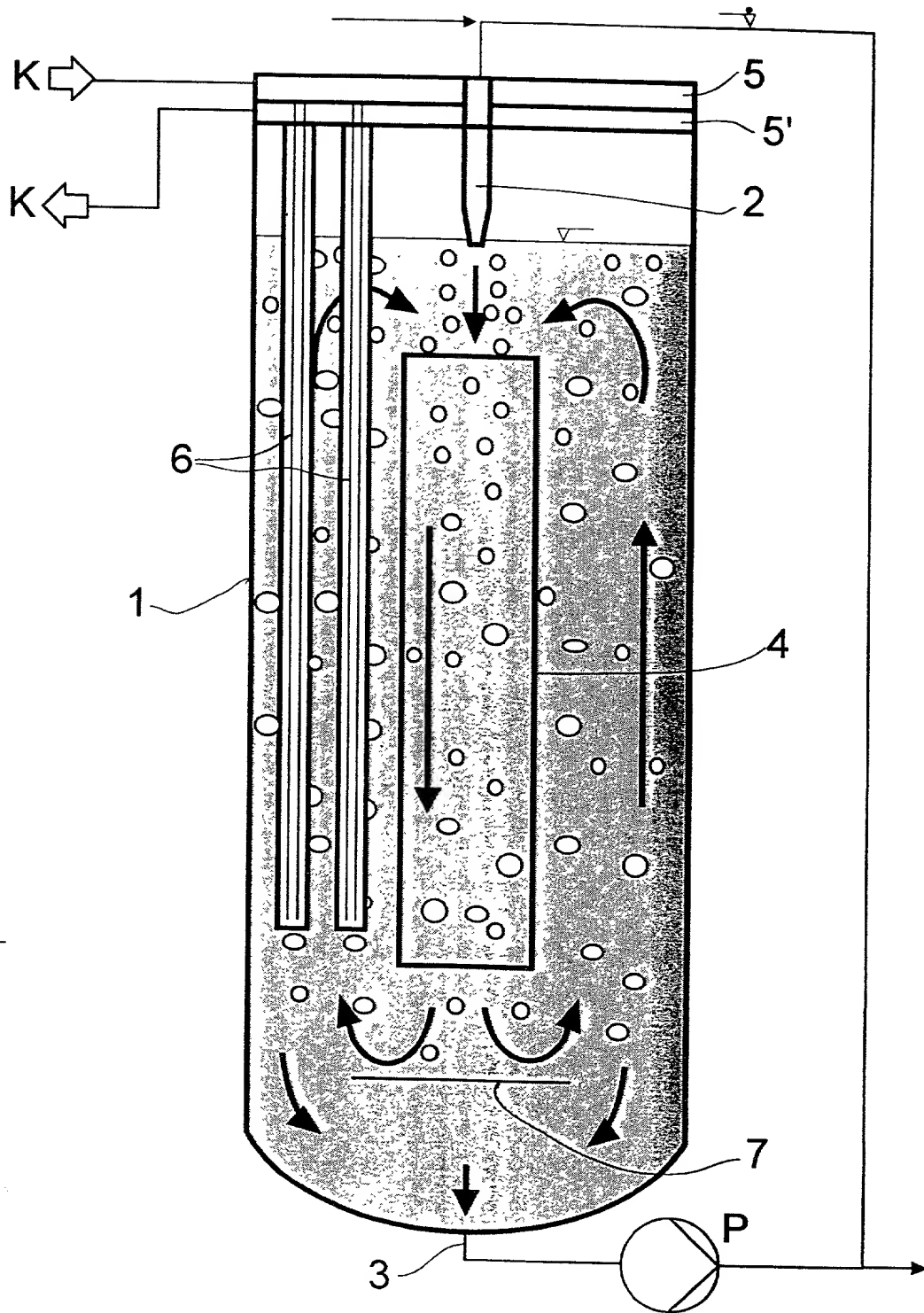
AS ENCLOSED TO IPER**We claim:**

1. A reactor (1) of high cylindrical construction for continuously carrying out gas-liquid-solid reactions, provided with a downward-directed jet nozzle (2) via which the starting materials and the reaction mixture are fed in and which is located in the upper region of the reactor, and provided with an offtake (3), preferably in the lower region of the reactor, via which the reaction mixture is conveyed via an external circuit back to the jet nozzle (2) by means of a pump (P), where a guide tube (4) which extends essentially over the total length of the reactor (1) with the exception of the reactor ends and has a cross-sectional area in the range from one tenth to one half of the cross-sectional area of the reactor (1) is located concentrically in the reactor (1), and the jet nozzle (2) is located above the upper end of the guide tube (4), preferably at a distance of from one eighth of the guide tube diameter to one guide tube diameter, or projects into the guide tube (4) to a depth up to a plurality of guide tube diameters, and a heat exchanger provided with heat exchange tubes is integrated into the annular space, wherein the heat exchanger tubes run parallel to the guide tube (4).
2. A reactor (1) as claimed in claim 1, wherein the heat exchanger tubes of the heat exchanger are welded in between plates.
3. A reactor (1) as claimed in claim 1 or 2, wherein the jet nozzle (2) is configured as a single-fluid nozzle and, optionally, a facility for introducing one or more gaseous reactants, preferably one or more, in particular from one to three, annular pipes having a plurality of orifices, in particular in the lower region of the reactor or distributed over the height of the reactor, is (are) additionally provided in the annular space between guide tube (4) and interior wall of the reactor.
4. A reactor (1) as claimed in claim 1 or 2, wherein the jet nozzle (2) is configured as a three-fluid or two-fluid nozzle.

5. A reactor (1) as claimed in any of claims 1 to 4, which has an aspect ratio l/d of from 3 to 10, preferably from 6 to 10.
6. A reactor (1) as claimed in any claims 1 to 5, wherein the ratio of the diameters of guide tube (4) and reactor (1) is in the range from 0.25 to 0.5, particularly preferably in the range from 0.28 to 0.33.
7. A reactor (1) as claimed in any of claims 1 to 6, wherein an impingement plate (6) is located in the region of the reactor below the lower end of the guide tube (4), preferably at a distance of one guide tube diameter.
8. A continuous process for carrying out gas-liquid or gas-liquid-solid reactions in a reactor (1) as claimed in any of claims 1 to 7, wherein the major part of the reaction mixture, corresponding to from 2 to 30 times, preferably from 5 to 10 times, the volume flow of the reaction mixture pumped around the external circuit flows in an internal loop through the guide tube (4) from the top downward and through the annular space between guide tube (4) and interior wall of the reactor from the bottom upward.
9. The use of an apparatus as claimed in any of claims 1 to 7 or a process as claimed in claim 8 for, in particular, strongly exothermic gas-liquid or gas-liquid-solid reactions, preferably for hydrogenations, oxidations, ethoxylations, propoxylations, hydroformylations or aldol condensations.

[illegible]

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2
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Declaration, Power of Attorney

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0050/049568

We (I), the undersigned inventor(s), hereby declare(s) that:

My residence, post office address and citizenship are as stated below next to my name,

We (I) believe that we are (I am) the original, first, and joint (sole) inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Reactor for continuously carrying out gas-liquid, liquid-liquid or gas-liquid-solid reactions

the specification of which

☒ is attached hereto.

☐ was filed on _____ as

Application Serial No. _____

and amended on _____.

☒ was filed as PCT international application

Number PCT/EP99/09059

on 23/11/1999

and was amended under PCT Article 19

on _____ (if applicable).

We (I) hereby state that we (I) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We (I) acknowledge the duty to disclose information known to be material to the patentability of this application as defined in Section 1.56 of Title 37 Code of Federal Regulations.

We (I) hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed. Prior Foreign Application(s)

Application No.	Country	Day/Month/Year	Priority Claimed
19854637.8	Germany	26 November 1998	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No

We (I) hereby claim the benefit under Title 35, United States Codes, § 119(e) of any United States provisional application(s) listed below.

(Application Number)

(Filing Date)

(Application Number)

(Filing Date)

We (I) hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

Application Serial No.

Filing Date

**Status (pending, patented,
abandoned)**

_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

And we (I) hereby appoint **Messrs. HERBERT. B. KEIL**, Registration Number 18,967; and **RUSSEL E. WEINKAUF**, Registration Number 18,495; the address of both being Messrs. Keil & Weinkauff, 1101 Connecticut Ave., N.W., Washington, D.C. 20036 (telephone 202-659-0100), our attorneys, with full power of substitution and revocation, to prosecute this application, to make alterations and amendments therein, to sign the drawings, to receive the patent, and to transact all business in the Patent Office connected therewith.

We (I) declare that all statements made herein of our (my) own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

1-00

Stefan Berg
NAME OF INVENTOR

Stefan Berg

Signature of Inventor

Date 15/02/2001

Mörscher Str.98a
67227 Frankenthal
Germany
Citizen of: Germany
Post Office Address: same as residence

DEX

2-00

Peter Zehner
NAME OF INVENTOR

Peter Zehner

Signature of Inventor

Date 15/02/2001

Erich-Kästner-Str.15
67074 Ludwigshafen
Germany
Citizen of: Germany
Post Office Address: same as residence

DEX

3-00

Regina Benfer
NAME OF INVENTOR

Regina Benfer

Signature of Inventor

Date 15/02/2001

Akazienweg 23
67122 Altrip
Germany
Citizen of: Germany
Post Office Address: same as residence

DEX

4-00

Jörn Müller
NAME OF INVENTOR

Jörn Müller

Signature of Inventor

Date 15/02/2001

Erwin-Brünisholzweg 10
67071 Ludwigshafen
Germany
Citizen of: Germany
Post Office Address: same as residence

DEX

5-00

Michael Nilles
NAME OF INVENTOR

Michael Nilles
Signature of Inventor

Date 15/02/2001

Bayernstr.48
67061 Ludwigshafen
Germany DEX
Citizen of: Germany
Post Office Address: same as residence

6-00

Ralf Schulz
NAME OF INVENTOR

Ralf Schulz
Signature of Inventor

Date 15/02/2001

Maulbronner Hof 35
67346 Speyer
Germany DEX
Citizen of: Germany
Post Office Address: same as residence

7-00

Dieter Stützer
NAME OF INVENTOR

Dieter Stützer
Signature of Inventor

Date 15/02/2001

Carl-Zimmermann-Str.21
67373 Dudenhofen
Germany DEX
Citizen of: Germany
Post Office Address: same as residence

TELEFON 06204 2200